MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2022/2023

PTH0016 MODERN PHYSICS AND THERMODYNAMICS

(Foundation in Engineering)

2 OCTOBER 2023
9:00 A.M. – 11:00 A.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 6 pages, excluding the cover page.
2. Answer all questions.
3. Write your answers on answer booklet provided.
4. Show all relevant steps to obtain maximum marks.

QUESTION 1 (15 MARKS)

a) Light is incidence on an equilateral triangle crown glass prism at an angle of 50° to one face, as shown in **Figure Q1(a)** below. Calculate the angle, θ, at which light emerges from the opposite face. Given that the index of refraction of crown glass prism is 1.5. [4.5 marks]

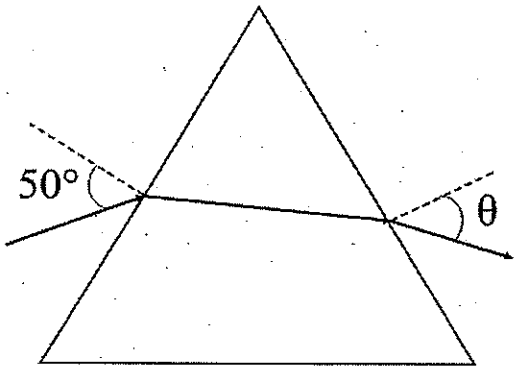

Figure Q1(a)

b) A beam of light is travelling inside a solid glass cube that has index of refraction 1.53. It strikes the surface of the cube from the inside as shown in **Figure Q1(b)** below.

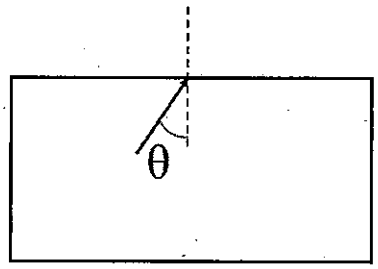

Figure Q1(b)

(i) If the cube is in air, at what minimum angle with the normal inside then glass will the light not enter the air at this surface? [1.5 marks]

(ii) What would the minimum angle in part (i) if the cube was immersed in water? Given the refractive index of water is 1.33. [1.5 marks]

c) Figure Q1(c) shows an object and its image formed by a thin lens.

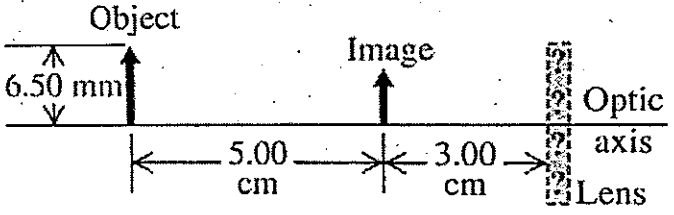

Figure Q1(c)

Continued...

(i) Calculate the focal length of the lens. [1.5 marks]

(ii) Determine the type of lens. [0.5 mark]

(iii) Calculate the height of the image formed. [1.5 marks]

(iv) Determine whether the image formed is real or virtual. [0.5 marks]

d) Your lecturer asks you to design a diffraction grating that will disperse the first-order visible spectrum through an angular range of 27° as shown in **Figure Q1(d)** below. Determine the number of slits per centimeter, N, that must be used for this grating. Hint: The wavelengths of visible spectrum range from 400 nm to 750 nm. Using trigonometry identity from the appendix for the sin of the sum of two angles.

[3.5 marks]

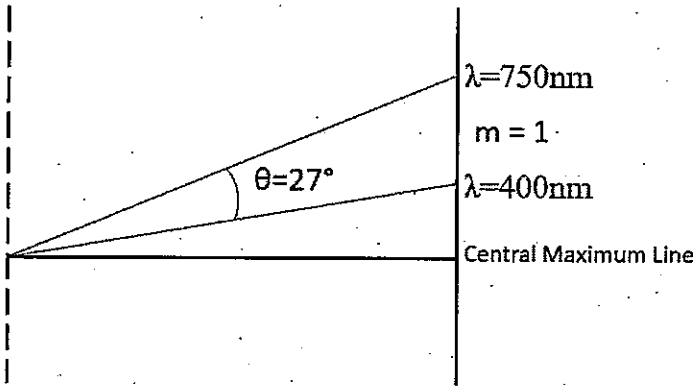

Figure Q1(d)

QUESTION 2 (10 MARKS)

a) The photoelectric work function of potassium is 2.3 eV. If light that has a wavelength of 260 nm falls on the potassium, calculate

(i) the stopping potentials in volts. [2 marks]

(ii) the maximum kinetic energy in eV. [1 mark]

(iii) the speed of these electrons. [2 marks]

b) A hydrogen atom initially in its ground level absorbs a photon, which excites the atom to the n = 4 level.

(i) Determine the wavelength of the photon. [2 marks]

(ii) If the hydrogen atom emits photon, show on an energy-level diagram, the possible transitions for the hydrogen atom to drop from n = 4 level to the ground level. [3 marks]

Continued...

QUESTION 3 (10 MARKS)

a) In many cases, cancer is treated by implanting small seeds of radioactive material into the tumor. The energy released from the decays kills the tumor. One isotope that is used is palladium (^{103}Pd), with a half-life of 17 days. If a typical grain contains 0.25 g of ^{103}Pd, calculate

(i) its initial number of nuclei present, N_o. [1.5 marks]

(ii) the decay constant, λ. [1.5 marks]

(iii) its initial activity rate, R_o, in Bq. [1.5 marks]

(iv) the activity rate, R, 68 days later in Bq. [1.5 marks]

(v) the number of nuclei present, N, 68 days later. [1.5 marks]

b) Consider the nuclear reaction below:

$$^{28}_{14}\text{Si} \rightarrow ^{24}_{12}\text{Mg} + \text{X}$$

where X is a nuclide.

(i) Determine the atomic number, Z, and the mass number, A, of nuclide X. [1 mark]

(ii) Calculate the energy released for this nuclear reaction in MeV. [1.5 marks]

Given the atomic mass unit:

$^{28}_{14}\text{Si} = 28.006927\text{u}$	$^{-1}_{0}\beta = 0.000549\text{u}$
$^{24}_{12}\text{Mg} = 23.985042\text{u}$	$^{1}_{0}\text{n} = 1.008665\text{u}$
$^{4}_{2}\text{He} = 4.002603\text{u}$	$^{1}_{1}\text{H} = 1.007825\text{u}$

QUESTION 4 (15 MARKS)

a) 0.45 kg of a metal at $100°C$ is added to 0.40 kg of water at $18°C$ in an isolated system. If the final temperature of the mixture is $25°C$,

(i) which of the material absorbed energy? Explain. [1.5 marks]

(ii) what is the specific heat capacity of the metal? [2 marks]

(iii) If the water is replaced with another material which has twice the specific heat capacity of water, but the mass is reduced by half, what will be the changes, if any, to the final temperature? [1.5 marks]

Given the specific heat capacity of water is 4186 $Jkg^{-1}K^{-1}$. Neglect any exchange of heat between the system with surroundings.

Continued...

b) Name the following thermodynamic changes.

(i) A gas expands or compressed at constant temperature. [1 mark]

(ii) A gas undergoes expansion or compression in which no heat enters or leaves the system. [1 mark]

(iii) A gas undergoes a process in which the pressure is kept constant. [1 mark]

c) Water with mass of 2.0 kg is held at constant volume in a container while 10.0kJ of energy is slowly added by a flame. The container is not well insulated, and as a result 2.0 kJ of energy leaks out to the surroundings.

(i) Name this thermodynamic process.

[1 mark]

(ii) What is the temperature increase of the water?
[Hint: use specific heat capacity of water $4.186\ x\ 10^3 J/kg°C$]

[3 marks]

d) A 2.0 mol sample of an ideal gas undergoes thermodynamic process as shown in Figure Q4. From A to B, the gas expands at constant temperature and 9600 J of heat enters the gas. From B to C, the gas is compressed at constant pressure and 7500 J of heat leaves the gas.

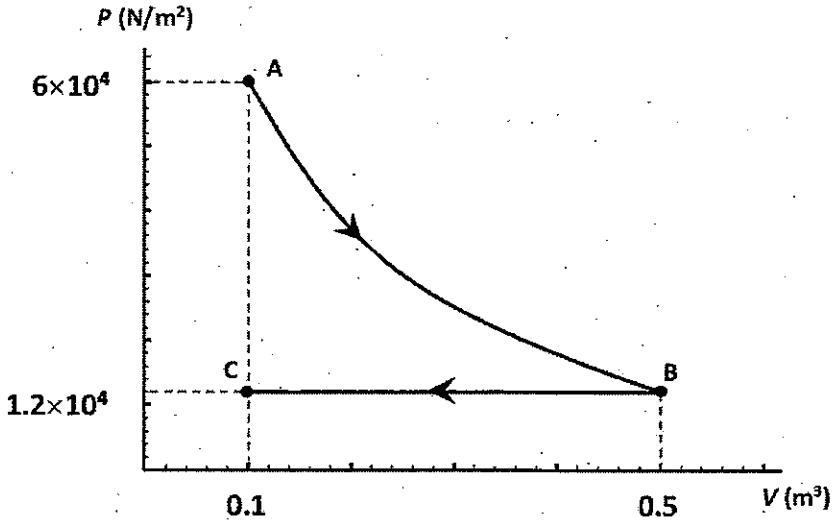

Figure Q4

Using the first law of thermodynamics, determine the change in internal energy of the gas in process BC.

[3 marks]

End of paper.

APPENDIX

LIST OF PHYSICAL CONSTANTS

Electron mass,	m_e	=	9.11×10^{-31} kg
Proton mass,	m_p	=	1.67×10^{-27} kg
Neutron mass,	m_n	=	1.67×10^{-27} kg
Magnitude of the electron charge,	e	=	1.60×10^{-19} C
Universal gravitational constant,	G	=	6.67×10^{-11} N m^2 / kg^2
Universal gas constant,	R	=	8.314 J/mol K
Hydrogen ground state,	E_0	=	13.6 eV
Boltzmann's constant,	k_B	=	1.38×10^{-23} J/K
Compton wavelength,	λ_c	=	2.426×10^{-12} m
Planck's constant,	h	=	6.63×10^{-34} J s
		=	4.14×10^{-15} eV s
Speed of light in vacuum,	c	=	3.00×10^{8} m/s
Rydberg constant,	R_H	=	1.097×10^{7} m^{-1}
Acceleration due to gravity of earth,	g	=	9.80 m/s^2
1unified atomic mass unit,	1 u	=	931.5 MeV/c^2
		=	1.66×10^{-27} kg
1 electron volt,	1 eV	=	1.60×10^{-19} J
Avogadro's number,	N_A	=	6.02×10^{23} mol^{-1}
Threshold of intensity of hearing,	I_0	=	1.0×10^{-12} W/m^2
Coulomb constant,	$k = \frac{1}{4\pi\varepsilon_0}$	=	9.0×10^{9} N m^2 /C^2
Permittivity of free space,	ε_0	=	8.85×10^{-12} C^2/N m^2
Permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ T m/A
1 atmosphere pressure,	1 atm	=	1.013×10^{5} N/m^2
		=	1.013×10^{5} Pa
Wien's displacement constant		=	2.90×10^{-3} mK
Speed of sound in air		=	343 m/s
Refractive index of air/vacuum	n	=	1.0
First Bohr Radius,	a_o	=	0.053 nm
Earth: Mass,	M_E	=	5.97×10^{24} kg
Radius (mean),	R_E	=	6.38×10^{3} km
Moon: Mass,	M_M	=	7.35×10^{22} kg
Radius (mean),	R_M	=	1.74×10^{3} km
Sun: Mass,	M_S	=	1.99×10^{30} kg
Radius (mean),	R_S	=	6.96×10^{5} km
Earth-Sun distance (mean),		=	149.6×10^{6} km
Earth-Moon distance (mean),		=	384×10^{3} km

LIST OF FORMULAS

$$\sin\theta_1 + \sin\theta_2 = 2\sin\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\cos\theta_1 + \cos\theta_2 = 2\cos\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\sin\left(\theta+\frac{\pi}{2}\right) = \cos\theta$$

$$\sin(\alpha\pm\beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$$

$$\tan\alpha = \frac{\sin\alpha}{\cos\alpha}$$

$\sin\theta \approx \tan\theta \approx \theta \ \ rad$ for small angles

$D(x, t) = D_M \sin(kx \pm \omega t \pm \phi)$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad f = \frac{R}{2} \qquad v = f\lambda$$

$$d\sin\theta = m\lambda \qquad d\sin(\theta) = \left(m+\frac{1}{2}\right)\lambda \qquad a\sin(\theta) = n\lambda$$

$$E_n = -\frac{mk^2e^4}{2\hbar^2}\left(\frac{1}{n^2}\right) \qquad r_n = \frac{\hbar^2}{mke^2}n^2 \qquad L = mvr_n = n\hbar$$

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right] \qquad \frac{1}{\lambda} = \frac{mk^2\ Z^2e^4}{4\pi\ c\hbar^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] \qquad \lambda = \frac{h}{p}$$

$$R = R_0e^{-\lambda t} \qquad \lambda = \frac{\ln 2}{T_{1/2}} \qquad Q = (M_X - M_Y - M_\alpha)\ c^2$$

$$pV = nRT \qquad k = \frac{R}{N_A} \qquad N = N_0e^{-\lambda t}$$

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta L} \qquad \frac{\Delta Q}{\Delta t} = e\sigma AT^4 \qquad \frac{\Delta Q}{\Delta t} = IeA\cos(\theta)$$

$$\overline{KE} = \frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT \qquad U = \frac{3}{2}nRT$$

$$Q = \Delta U + W \qquad W = \int dW = \int_{V_i}^{V_f} PdV \qquad W = P\Delta V$$